10/533937
Rec'd PCT/PTO 03 MAY 2005
PCT/US2003/002818

~~APPARATUS FOR INCREASING THE QUALITY OF SOUND FROM AN ACOUSTIC SOURCE~~

FIELD OF THE INVENTION

[0001] The invention relates to an enclosure for an acoustic source. In particular, the invention relates to an apparatus for increasing the quality of sound from an acoustic source, and that is particularly suited for improving acoustic output of bass sounds.

BACKGROUND OF THE INVENTION

[0002] Acoustics technology, and in particular stereo technology, has advanced to meet the demand for improved sound quality. The rising popularity in home theater systems and related sound technologies has refocused the stereo industry towards improved and more efficient sound systems. Sound systems are also an integral part of vehicles of all types. Advances in acoustics and electronics technology have resulted in smaller and more efficient delivery systems. Nevertheless, acoustic principles demand relatively lengthy transmission lines or acoustic paths. For example, known acoustic paths may extend up to several feet. Space restrictions in houses, vehicles, and mobile stereos, however, limit the use of such acoustic paths and the relatively large enclosures that house them.

[0003] Production of sound within an enclosure, whereby acoustic waves are directed along an acoustic path, is a critical aspect of the process. Specifically,

sound is produced by an acoustic source, for example, a driver, and then directed along an acoustic path to an opening. The shape of the acoustic path affects the quality of sound exiting the outlet.

[0004] Existing apparatus address the problem of improving sound quality while minimizing space requirements by incorporating acoustic paths having sharp bends (*i.e.,* folded paths) such that the acoustic path fits within the enclosure. The folded or labyrinth designs for acoustic paths require sharp bends that disrupt airflow, and thus degrade sound quality and increase mechanical noise. Further, known devices incorporate relatively long acoustic paths that are unsuitable for use in close quarters (*e.g.,* apartments and car stereos).

[0005] Known apparatus also address the problem of minimizing space requirements by incorporating helical acoustic paths, wherein structures housed within the enclosure define a single helix acoustic path. The single helix design, however, fails to recognize the benefits of a double helix structure. Specifically, the single helix design limits the air mass (*i.e.,* acoustic mass) that provides the medium for transmitting the acoustic waves.

[0006] For example, U.S. Patent Nos. 5,824,969 (the `969 patent) and 6,078,676 (the `676 patent) to Takenaka disclose a speaker system having a single spiral sound passage. Both Takenaka patents disclose a lower T-joint for supporting an outer tube, an inner tube for supporting a partition plate arranged in a spiral pattern, an upper T-joint connected to the top end of the

outer tube, and a speaker unit secured to the upper T-joint. As described, the Takenaka patents rely on a single passage for directing sound radiating from the rear of the speaker. Specifically, the Takenaka patents incorporate a single inlet opening leading into a single passage that is in communication with a single outlet opening. Although both patents address the problem of sharp or acute bends in the sound passage, the `969 and `676 patents fail to recognize the advantages of incorporating two sound passages in the shape of a double helix. Further, the Takenaka patents describe the use of a dual tube structure wherein the inner tube supports the partition plate. Thus, Takenaka further restricts the limited area of the single sound passage—and thus total medium (*i.e.*, air) for transmitting sound—by incorporating a support structure for the spiral plate. Thus there exists a need for an apparatus that maximizes the total area of the sound passage without adversely affecting the overall size of the enclosure housing the acoustic source and acoustic guide.

[0007] Still other known apparatus incorporate double helix channels into an enclosure, yet position the channels around the periphery of the driver and around an inner sleeve that supports the driver at a front end. In this configuration, inlets for directing sound into the channels are adjacent the rear end of the inner sleeve and outlets of the passage are adjacent the front of the driver. This design, wherein the radius of the acoustic channel is a fraction of the total radius of the enclosure or inner sleeve, recognizes the need to maximize space, yet sacrifices sound quality by directing the sound from the driver in opposing directions (*i.e.*,

front to rear and then rear to front). The relatively small channels tend to create mechanical resonance, increase harmonic distortion, and restrict low frequency reproduction.

[0008] For example, U.S. Patent No. 6,062,339 to Hathaway describes an enclosure for housing a loudspeaker. Specifically, Hathaway discloses an outer sleeve that supports and surrounds an inner sleeve, a loudspeaker connected to a front end of the inner sleeve, and an insert positioned between the outer sleeve and inner sleeve. The insert defines two spiral channels that surround the inner sleeve. The channels direct sound advancing from the rear of the front-mounted speaker, around the inner sleeve (*i.e.*, between the inner and outer sleeve), and out of the front of the enclosure. Hathaway relies upon two spiral channels that wind around the outer surface of the inner sleeve that supports the loudspeaker. Thus, the sound must travel in opposing directions before exiting the enclosure. Specifically, the sound must travel rearward the length of the inner sleeve, and then forward through the channels between the inner and outer sleeve. Thus, Hathaway fails to recognize the benefits of a pair of acoustic paths having the shape of a double helix that effectively doubles the volume of air (*i.e.*, medium) for transmitting the sound. Stated differently, Hathaway recognizes the need to maximize space by wrapping the channels around the inner sleeve, yet sacrifices sound quality by directing the sound from the driver in opposing directions (*i.e.*, front to rear and then rear to front). Accordingly, Hathaway fails to address the problem of maximizing the radius—and thus the total area—of the channels. Unfortunately,

the structure of Hathaway creates mechanical resonance, increase harmonic distortion, and restrict low frequency reproduction.

[0009] Accordingly, there exists a need for an apparatus for improving the quality of sound from an acoustic source housed within an enclosure that directs sound in one direction in such a manner to dampen mechanical resonance, reduces harmonic distortion, and extends low frequency reproduction.

[0010] Known devices also include six or more resonant antinodes along the acoustic path that cause impedance variations at specific frequencies, and therefore creates uneven amplitude response. One option to counteract the uneven amplitude response is to incorporate damping material into the inlets of the acoustic paths. However, the addition of damping material into the inlets reduces the efficiency of the system, and therefore is a less desirable option. Moreover, the amount of damping material is dictated by the amount of available free space in the enclosure and acoustic path. Thus, a need exists for an enclosure and acoustic guide that does not require damping material to lessen uneven amplitude response.

[0011] A more attractive option in addressing the failures above is to increase the total area of the acoustic path without increasing the total size of the enclosure and without enhancing mechanical resonance, increasing harmonic distortion, or restricting low frequency reproduction. In this fashion, sound quality of the apparatus is not sacrificed for smaller sizes.

OBJECT AND SUMMARY OF THE INVENTION

[0012] It is therefore an object of the present invention to provide an apparatus capable maximizing the total area of a sound passage with an enclosure, without adversely affecting the overall size of the enclosure housing the acoustic source and acoustic guide.

[0013] Another object of the invention is to provide an apparatus for improving the quality of sound from an acoustic source housed within an enclosure that directs sound in one direction in such a manner to dampen mechanical resonance, reduce harmonic distortion, and extend low frequency reproduction.

[0014] Yet another object of the invention is the provision of an enclosure housing an acoustic guide that does not require damping material to lessen uneven amplitude response.

[0015] The invention meets these objectives with an apparatus capable of directing acoustic waves from an acoustic source housed within an enclosure that dampens mechanical resonance, reduces harmonic distortion, and extends low frequency reproduction of sound. These objectives are accomplished by maximizing the total area of the acoustic paths without increasing the space required to operate the apparatus. In particular, the invention is an apparatus comprised of a hollow enclosure that substantially surrounds an acoustic guide, an acoustic source secured to one end of the hollow enclosure, a pair of paths in the shape of a double helix defined by the acoustic guide, and a pair of acoustic

inlet openings and a pair of acoustic exit openings in communication with the acoustic paths.

[0016] The foregoing and other objects and advantages of the invention and the manner in which the same are accomplished will become clearer based on the following detailed description taken in conjunction with the accompanying drawings in which:

Brief Description of the Drawings

[0017] Figure 1 is a perspective view of a preferred embodiment of the apparatus as incorporated into a floor unit for a home stereo system that depicts a hollow enclosure, an acoustic source, an acoustic guide, a pair of acoustic inlet openings, a pair of acoustic paths, a driver, a support leg, and acoustic waves flowing from the driver and into the pair of acoustic paths.

[0018] Figure 2 is a partial perspective view of the preferred embodiment of the invention that depicts a second end of the hollow enclosure, a pair of acoustic exit openings, webbing for preventing debris from entering the acoustic exit openings, and the acoustic waves flowing out of the pair of acoustic exit openings.

[0019] Figure 3 is a partial perspective view of the preferred embodiment of the invention depicting the double helix shape of the acoustic guide, the double helix shape of the pair of acoustic paths, and the acoustic waves flowing into the acoustic inlet openings.

[0020] Figure 4 is a side view of the preferred embodiment of the invention illustrating the hollow

enclosure, the acoustic source and its spaced relationship to the acoustic guide, the empty chamber, the acoustic guide and its pitch, the pair of acoustic paths, the positional relationship of the acoustic inlet openings substantially perpendicular to the acoustic waves, and the acoustic waves entering the acoustic inlet openings, traveling along the acoustic path, and exiting the pair of acoustic exit openings.

[0021] Figure 5 is an enlarged partial side sectional view of an alternative embodiment of the invention depicting the acoustic source connected to the first end of the acoustic guide and the acoustic guide mounted in grooves formed in the hollow enclosure.

[0022] Figure 6 is an enlarged partial side sectional view of an alternative of the invention illustrating the positional relationship of the acoustic inlet openings substantially parallel to the acoustic waves.

Detailed Description of the Invention

[0023] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which a preferred embodiment of the invention is shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

[0024] The term "wave", and in particular "acoustic wave", will refer to a disturbance traveling through a medium, for example, a sound wave traveling through an air mass. Hence, the terms wave, acoustic wave, and sound wave may be used interchangeably.

[0025] It will be understood that as used herein the term the term "acoustic path" refers to a passage that directs acoustic waves.

[0026] The term "damping" as used herein refers to the reduction of movement of a speaker cone due to the electromechanical characteristic of the speaker driver and suspension, the effect of frictional losses inside a speaker enclosure, or electrical means.

[0027] Those skilled in the art will appreciate that the term "pitch" refers to the distance from any point on a side edge of the double helix-shaped acoustic guide to the corresponding point on an adjacent edge measured parallel to the longitudinal axis of the guide. Stated differently in terms of a screw, the pitch is the distance from any point of a thread of the screw to the corresponding point on an adjacent thread measured parallel to the longitudinal axis of the screw.

[0028] The term "oblique" refers to the positional relationship of one element to another element whereby one element is neither parallel nor perpendicular to the other element.

[0029] It will be further understood by those skilled in the art that the term "double helix" refers to the structural arrangement of the acoustic guide that consists of two continuous surfaces that extend outwardly

at an oblique angle from the longitudinal axis of the acoustic guide.

[0030] It will also be appreciated that the term "circumference" refers to the boundary line of a structure.

[0031] Further, the term "radius" refers to the distance of a straight-line segment that joins the center of a circular or spiral structure (*e.g.*, double helix structure) with any point on its circumference.

[0032] It will also be understood that the term "acoustic source" refers to any number of devices capable of producing noise or acoustic waves (*e.g.*, a stereo driver, a speaker, or resonator).

[0033] It will be further appreciated by those of ordinary skill in the art that, as used herein, the concept of an element "substantially surrounding" another element does not necessarily imply that the elements are contiguous (*i.e.*, in intimate contact). Rather, as used herein, the concept of one element substantially surrounding another element is meant to describe the relative positions of the elements within the structure, respectively.

[0034] It will be further appreciated by those of ordinary skill in the art that, as used herein, the concept of an element being "between" two other elements does not necessarily imply that the three elements are contiguous (*i.e.*, in intimate contact). Rather, as used herein, the concept of one element between two other elements is meant to describe the relative positions of the elements within the structure, respectively.

Similarly, as used herein, the concept of an element being connected to a second element by a third element, "opposite" the second element, merely describes the relative positions of the first and second elements within the structure.

[0035] It will be understood to those skilled in the art that the concept of an element being "adjacent" another element does not necessarily imply that the elements are contiguous (*i.e.*, in intimate contact). Rather, as used herein, the concept of an element being adjacent another element is meant to describe the relative positions of the elements wherein the elements are in close proximity. Furthermore, it will be understood that the concept of one element being adjacent another element does not necessarily imply contact, but may imply absence of anything of the same kind between the elements.

[0036] In addressing the quality of sound produced by acoustic source housed within an enclosure, those skilled in the art will recognize several factors affecting resonance. In acoustic terms, the factors are as follows. The magnification of resonance factor of any resonant device or circuit is defined as Q. For example, a driver with a high Q is more resonant that a driver with a low Q. Further, it will be understood that the electrical Q of the driver is represented as Qes, the mechanical Q of the driver is represented as Qms, and the total Q is represented as Qts.

[0037] An overall view of the apparatus **10** for increasing the quality of sound from an acoustic source housed within an enclosure as incorporated in a home

stereo system and which depicts features of the present invention is set forth in Figure 1. A preferred embodiment of the apparatus **10** includes a hollow enclosure **11**, an acoustic guide **12**, at least one leg **13**, an acoustic source **14**, a pair of acoustic paths **15**, a pair of acoustic inlet openings **20**, and a pair of acoustic exit openings **21**. It will be appreciated by those skilled in the art that the present invention may be incorporated into a variety of sound systems to include vehicle stereos, portable stereos, home entertainment systems, amplifiers, and musical instruments (*e.g.*, keyboard instruments such as pianos).

[0038] As depicted in Figure 4, the hollow enclosure **11** substantially surrounds the acoustic guide **12**. The hollow enclosure **11** includes a first end **22**, a second end **23**, an interior surface **24**, and an exterior surface **25**. As configured, edges **16** of the acoustic guide **12** abut the interior surface **24** of the hollow enclosure **11**. In a preferred embodiment, the hollow enclosure **11** is substantially circular and substantially surrounds the acoustic guide **12**. Alternative embodiments of the invention may include a hollow enclosure **11** that is substantially oval in shape.

[0039] The acoustic guide **12** is preferably mounted to the interior surface **24** of the hollow enclosure **11**. In a preferred embodiment, the acoustic guide **12** is mounted to the interior surface **24** of the hollow enclosure **11** by adhesive **30** (*see* Figure 4). It will be understood however that the acoustic guide **12** may be mounted to the interior surface **24** of the hollow enclosure **11** with foam rubber, hook-and-loop fasteners, or the like.

Alternatively, the acoustic guide **12** may be mounted into grooves **18** formed in the interior surface **24** of the hollow enclosure **11** (*see* Figure 5). The grooves **18** formed in the interior surface **24** of the hollow enclosure **11** correspond to the edges **16** of the acoustic guide **12**. In this fashion, the acoustic guide **12** can be screwed into the hollow enclosure **11**.

[0040] As configured in a preferred embodiment of the invention illustrated in Figure 4, the acoustic guide **12** is shaped in the form of a double helix and includes a first end **31** and a second end **32**. The hollow enclosure **11** and the acoustic guide **12** of Figure 4 define a common axis. The acoustic guide **12** is preferably made from polymeric material such as polyethylene or polypropylene. It will be understood however that the acoustic guide **12** may be formed from metal, wood, synthetic resin, glass, or ceramic.

[0041] In the preferred embodiment of Figure 4 the first end **31** of the acoustic guide **12** is spaced from the acoustic source **14**. This preferred embodiment includes an empty chamber **33** defined by the interior surface **24** of the hollow enclosure **11**, the first end **22** of the hollow enclosure, and the first end **31** of the acoustic guide **12**. Advantageously, the empty chamber **33** provides sufficient damping of, for example, a speaker cone of the acoustic source **14**. Preferably the pair of acoustic inlet openings **20** are spaced less than 6 inches from a diaphragm of the acoustic source **14** assuming a medium size driver (*i.e.*, 10 inch subwoofer). Stated differently, the pair of acoustic inlet openings **20** is preferably spaced less than 2 inches from the rear of the

driver. Accordingly, it is possible to construct the present invention such that the length of the hollow enclosure **11** is approximately 22 inches in length. It will be understood that the spacing will vary depending upon the size and type of subwoofer provided.

[0042] Figure 5 depicts an alternative embodiment of the invention, wherein the first end **31** of acoustic guide **12** is connected or immediately adjacent to the acoustic source **14** in a close-coupled arrangement. This configuration minimizes the space required for the hollow enclosure **11** without sacrificing the quality of sound. The positioning of the first end **31** of the acoustic guide **12** and the acoustic source **14**—wherein the first end of the acoustic guide is connected or immediately adjacent the acoustic source—minimizes the volume (*i.e.*, box volume) of space between the acoustic source **14** and the acoustic guide **12**. By minimizing box volume, the arrangement of the first end **31** of the acoustic guide **12** and the acoustic source **14** maintains the total Q (Q_t) of the empty chamber **33** above 1. The close-coupled arrangement, however, requires a driver with a high mechanical Q (Q_{ms}) (*e.g.*, 5 or greater) relative to electrical Q (Q_{es}) and total Q (Q_{ts}).

[0043] As illustrated in Figure 4, the radius of the acoustic guide **12** is substantially equal to the radius of the hollow enclosure **11**. Advantageously, the incorporation of the double helix shape into the acoustic guide **12** maximizes the total area of the pair of acoustic paths **15**. Stated differently, the acoustic paths **15** extend the entire radius of the hollow enclosure **11** to

thereby provide increased air mass that serves as a transmitting medium.

[0044] The pitch **P** of the acoustic guide **12** facilitates the transmission of a variety of acoustic waves **34** (*see* Figure 4). As described above and with reference to Figure 4, "pitch" **P** refers to the distance from any point on an edge **16** of the double helix-shaped acoustic guide **12** to the corresponding point on an adjacent edge **17** measured parallel to the longitudinal axis of the acoustic guide **12**. In a preferred embodiment, the pitch **P** of the acoustic guide **12** is between about .0625 to 4 inches (*i.e.*, .15875 to 10.16 centimeters (cm), respectively) and more preferably between about 1 to 2 inches (*i.e.*, 2.54 to 5.08 cm).

[0045] Referring to Figures 1 and 3, the first end **31** of the acoustic guide **12** defines the pair of acoustic inlet openings **20**. The pair of acoustic inlet openings **20** is capable of admitting acoustic waves **34** produced by the acoustic source **14** into the pair of acoustic paths **15**. Preferably, the acoustic source **14** is a driver, but it will be understood that the acoustic source may be any number of devices that produce acoustic waves (*e.g.*, resonator). In a preferred embodiment, the acoustic source **14** is secured to the first end **22** of the hollow enclosure **11**. With reference to the orientation of the acoustic guide **12** depicted in Figure 4, the pair of acoustic inlet openings **20** is preferably oriented substantially coplanar with respect to one another. Nevertheless, it will be understood that the pair of acoustic inlet openings **20** may be oriented in a non-coplanar configuration. The orientation of the pair of

acoustic inlet openings **20** depends upon the type of sound (*e.g.*, bass) upon which the operator is trying to improve.

[0046] The second end **32** of the acoustic guide **12** defines the pair of acoustic exit openings **21** as illustrated in Figures 2 and 4. The pair of acoustic exit openings **21** is in communication with the pair of acoustic inlet openings **20** and the pair of acoustic paths **15**. Advantageously, the pair of acoustic inlet openings **20** separate acoustic waves **34** emanating from the acoustic source **14** and direct the acoustic waves **34** along the pair of acoustic paths **15** to the acoustic exit openings **21**. In the preferred embodiment of Figure 4, the pair of acoustic exit openings **21** is oriented substantially coplanar with respect to one another. Nevertheless, it will be understood that the pair of acoustic exit openings **21** may be oriented in a non-coplanar configuration. The orientation of the pair of acoustic exit openings **21** depends upon the type of sound (*e.g.*, bass) upon which the operator is trying to improve.

[0047] Still referring to Figure 4, the pair of acoustic exit openings **21** is preferably oriented substantially coplanar with respect to the second end **23** of the hollow enclosure **11**. It will be understood, however, that the pair of acoustic exit openings **21** may be oriented in a non-coplanar relationship with respect to the second end **23** of the hollow enclosure **11**. The orientation of the pair of acoustic exit openings **21** with respect to the second end **23** of the hollow enclosure **11** depends upon the type of sound upon which the operator is trying to improve.

[0048] The pair of exit openings **21** may also include webbing **35** that prevents the admission of debris into the exit openings **21** (*see* Figures 1 and 2). The webbing **35** is preferably formed from foam, but may be formed from wire or textile material (*i.e.*, woven or non-woven textile material).

[0049] As illustrated in Figure 4 depicting a preferred embodiment, the pair of acoustic inlet openings **20** and the pair of acoustic exit openings **21** are oriented substantially parallel to one another. Further, as configured in the preferred embodiment, the pair of acoustic inlet openings **20** and the pair of acoustic exit openings **21** are oriented in a plane that is substantially perpendicular to the path of acoustic waves **34** produced by the acoustic source **14** (*see* Figure 4). This configuration minimizes the travel distance necessary for the acoustic waves **34** to reach the pair of acoustic inlet openings **20**, thereby reducing the likelihood of diminished sound quality. Moreover, this design reduces the number of surfaces off of which the waves **34** must reflect in order to reach the pair of acoustic inlet openings **20**, thereby minimizing out-of-phase reflection of the acoustic waves **34**.

[0050] As shown in Figures 1 and 4, the acoustic source **14** is secured to the first end **22** of the hollow enclosure **11**. In operation, acoustic waves **34** emanate from the rear of the acoustic source **14** and travel directly into the pair of acoustic inlet openings **20**.

[0051] In an alternative embodiment illustrated in Figure 6, the pair of acoustic inlet openings **20** and the pair of acoustic exit openings **21** (*see* Figures 2 and 3)

may be oriented in a plane that is substantially parallel to the path of acoustic waves **34** produced by the acoustic source **14**. In the alternative embodiment, the acoustic source **14** is secured to one side of the hollow enclosure **11**. Accordingly, the acoustic waves **34** emanate from the rear of the acoustic source **14**, reflect against the sides of the first end **22** of the hollow enclosure **11**, and then into the pair of acoustic inlet openings **20**.

[0052] Preferably, the pair of acoustic inlet openings **20** and the pair of acoustic exit openings **21** are substantially semi-circular in shape. Nevertheless, it will be understood that the pair of acoustic inlet openings **20** and acoustic exit openings **21** may be any number of shapes to include circular, square, triangular, octagonal, elliptical, or hexagonal.

[0053] The acoustic guide **12** defines the pair of acoustic paths **15** in the shape of a double helix. The pair of acoustic paths **15** is positioned between the pair of acoustic inlet openings **20** and the pair of acoustic exit openings **21**. Accordingly, the pair of acoustic paths **15** directs acoustic waves **34** from the pair of acoustic inlet openings **20** to the pair of acoustic exit openings **21**. As depicted in Figure 4, the radius of each acoustic path **15** is substantially equal to the radius of the hollow enclosure **11**. Advantageously, the acoustic paths **15** maximize the total air mass of the acoustic paths without adversely affecting the overall size of the enclosure.

[0054] The invention may also include at least one support leg **13** secured to the exterior surface **25** of the hollow enclosure **11** as illustrated in Figures 1 and 2.

The leg **13** is preferably connected to the hollow enclosure **11** such that the leg extends substantially perpendicular to the longitudinal axis of the hollow enclosure **11** to prevent rotational movement.